

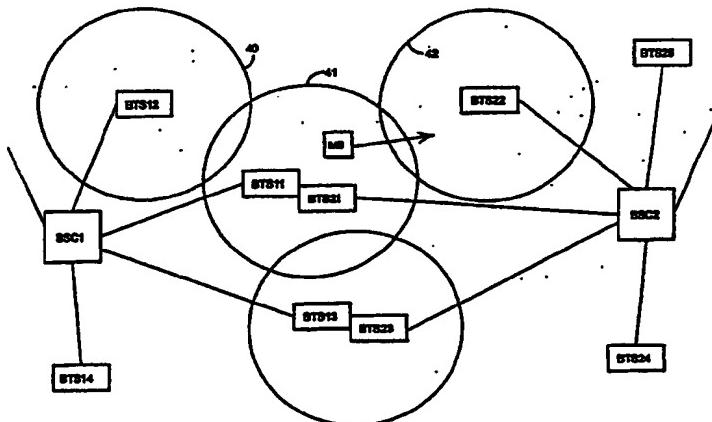


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(71) Applicant ( <i>for all designated States except US</i> ): NOKIA TELECOMMUNICATIONS OY [FI/FI]; Mäkkylän puistotie 1, FIN-02600 Espoo (FI).  (72) Inventor; and (75) Inventor/Applicant ( <i>for US only</i> ): JOLMA, Petri [FI/FI]; Harakkakuja 6 G 49, FIN-02600 Espoo (FI).  (74) Agent: TEKNOPOLIS KOLSTER OY; Oy Kolster Ab, Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).		

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## (54) Title: HANDOVER METHOD AND CELLULAR COMMUNICATIONS SYSTEM



## (57) Abstract

The invention relates to a cellular communication system and a method for a handover in a cellular communication system which comprises at least one base station (BTS) per each cell, which base station is controlled by a base station controller (BSC) which controls one or more base stations, and which base station controller with the base stations under its control form a base station system (BSS). In order that interference-free handover be achieved in accordance with the invention, the service areas of base stations under different base station controllers (BSC1, BSC2) at the border of two or more base station systems (BSS1, BSS2) at least partly overlap, and that as a terminal equipment (MS) moves from one base station system (BSC1) to another (BSC2), the handover is carried out so that as the terminal equipment moves into a cell served by two or more base stations (BTS11, BTS21) which belong to areas of different base station controllers, the terminal equipment carries out a soft handover from the hold cell (BTS12) to the new cell (BTS11), and as it further moves towards the cell border, it carries out a hard handover from the base station (BTS11) of the old base station system (BSS1) to the base station (BTS21) of the new base station system (BSS2) the service area of which base station (BTS21) at least partly overlaps with the previous base station.

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## Handover method and cellular communication system

The present invention relates to a method for a handover in a cellular communication system which comprises at least one base station per each cell, which base station is controlled by a base station controller which controls one or more base stations, and which base station controller with the base stations under its control forms a base station system.

The present invention is especially well applicable to CDMA cellular communication systems. A CDMA (Code Division Multiple Access) system is a multiple access method which is based on spread spectrum technology and whose application in cellular communication systems has lately been initiated along with the earlier FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access) technologies. The CDMA technology has several advantages over the earlier methods, such as spectral efficiency, simple frequency planning and traffic capacity.

In a CDMA method, the narrow-band data signal of the user is multiplied by a spreading code of much wider bandwidth to a relatively wide traffic channel band. In the known experimental cellular network systems, the bandwidths used on traffic channels include, for example, 1,25 MHz, 10 MHz and 25 MHz. In the multiplying process, the data signal spreads to the whole band used. All users transmit simultaneously by using the same frequency band, i.e. traffic channel. A separate spreading code is employed for each connection between a base station and a subscriber terminal equipment, and the signals from the users can be identified from each other in the receivers on the basis of the spreading code of each connection.

In a CDMA system, then, all users transmit on the same, relatively wide frequency band. The traffic channel of the user is formed by a spreading code which is characteristic to the connection and on the basis of which the transmission of the user is identified from the transmissions of other connections, as described earlier. As a considerable number of spreading codes are usually in use, the CDMA system does not have a definite capacity limit like the FDMA and the TDMA systems. The CDMA system is a so-called interference restricted system in which the number of users is restricted by the level of interference allowed for one user to cause to another. As the spreading codes of the users in the systems in use are not fully uncorrelated with regard to spreading codes employed by the neighbouring cell, especially, simultaneous users cause interference to each other to some extent. This kind of interference caused by one user to another is referred to as multiuser interference. As the number of users increases, the level of interference they cause to each other consequently increases, and, as the number of users reaches a certain level, the interference increases so as to damage the quality of the connections. In the system, it is possible to determine an interference level not to be exceeded, and so to set a limit to the number of simultaneous users, i.e. to the capacity of the system. A temporary exceeding of this number can, however, be allowed, which means that some of the connection quality is sacrificed at the expense of capacity.

In a typical mobile station environment, signals between a base station and a mobile station travel by several different paths between the transmitter and the receiver. This multipath propagation is mainly caused by signals reflecting from the

surrounding surfaces. Signals that have travelled through different paths arrive at the receiver at different times due to different delays in the propagation time. The CDMA method differs from the conventional FDMA and TDMA method in that in the CDMA method, the multipath propagation can be utilized in the reception of signals. As a CDMA receiver solution, a so-called RAKE receiver consisting of one or more RAKE branches is commonly employed. Each branch is an independent receiving unit whose function is to compose and demodulate one received signal component. Each RAKE branch can be controlled to synchronize into a signal component that has travelled along a path of its own, and in a conventional CDMA receiver the signals of the receiving branches are advantageously combined, and thus, a good-quality signal is obtained.

It is possible that the signal components received by the branches of a CDMA mobile station receiver have been transmitted by one or more base stations. In the latter case, a so-called macro-diversity is in question, i.e. a diversity mode by which the quality of a connection between a mobile station and a base station can be improved. In CDMA cellular communication networks, macro-diversity, also referred to by the term soft handover, is employed for ensuring the operation of power control at the base station border areas, and for enabling a seamless handover. Thus, a mobile station employing macro-diversity simultaneously communicates with two or more base stations. All connections transmit the same information. As an example of a cellular communication system employing macro-diversity, the publication EIA/TIA Interim Standard: Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread

Spectrum Cellular System, TAI/EIA/IS-95, July 1993 is referred to.

Thus, in a macro-diversity situation, the terminal equipment can combine signals transmitted by different base stations. At the base station end, signals received by two separate base stations from the terminal equipment are combined at the first possible point which in most cases is the base station controller in whose area the base stations are located. If the base stations to which the terminal equipment is coupled are under control of different base station controllers, the practical implementation of a soft handover will be considerably complicated, because in such a case the connecting has to be carried out in a mobile services switching centre.

Older cellular communication systems, such as GSM, NMT and AMPS, employ a so-called hard handover in which the base station change is carried out by first breaking the connection to the old base station and then establishing connection to a new base station. In such a case, then, the terminal equipment is coupled to only one base station at a time. Hard handover technology is simpler to implement than soft handover. So far, hard handover has not been applied to CDMA systems, because it causes instability in power control. Because the system is interference restricted, accurate power control is a prerequisite for the operation of a CDMA system.

It is an object of the present invention to make it possible to use both soft and hard handover especially in a CDMA cellular communication system so that the advantages of both methods are obtained.

This is achieved by a method of the type set forth in the introductory section, characterized in that at the border of two or more base station systems, the

service areas of base stations under different base station controllers at least partly overlap, and that as a terminal equipment moves from one base station system to another, the handover is carried out so that as the terminal equipment moves into a cell served by two or more base stations which belong to areas of different base station controllers, the terminal equipment carries out a soft handover from the old cell to the new cell, and as it further moves towards the cell border, it carries out a hard handover from the base station of the old base station system to the base station of the new base station system the service area of which base station at least partly overlaps with the previous base station.

The invention further relates to a cellular communication system which comprises in each cell at least one base station controlled by a base station controller which has one or more base stations under its control, and which base station controller with said base stations under its control form a base station system. It is characteristic of a cellular communication system of the invention that at the border area of two or more base station systems, the service areas of base stations under control of different base station controllers at least partly overlap.

By the method of the invention, the power control of the network remains stable even when hard handover is employed, and the complexity of a soft handover at the border between two base station controllers can be avoided.

By the invention, the use of soft handover and hard handover technology can be combined so that if a subscriber terminal equipment is within a base station system, it is handed over from a base station to another by a soft handover, and the base station change to the

area of the new base station controller is carried out by a hard handover. In an implementation in accordance with the invention in which service areas of base stations which are at the border of base station controllers overlap, the problems the hard handover earlier caused to the power control of the system are avoided.

In the following, the invention will be described in closer detail with reference to the accompanying drawings in which

figure 1 is a block diagram exemplary illustration of the structure of a cellular communication system,

figure 2 is an exemplary illustration of a cellular communication system in accordance with the invention,

figures 3a - 3c are exemplary illustrations of a base station configuration, and

figure 4 illustrates the operation of the method of the invention.

Figure 1 illustrates a typical structure of a cellular communication system. The area covered by the system is typically divided into base station systems BSS each of which consists of a base station controller BSC and base stations BTS coupled to said BSC, which base stations serve the subscriber terminal equipments MS in their service area. The base station controllers, in turn, are typically coupled to mobile services switching centres MSC from which calls are routed to the fixed network and other mobile services switching centres.

In a typical system employing a soft handover, the control functions of the base station system BSS are concentrated in a base station controller BSC. A base station BTS handles the operations of the physical

layer, such as transmitting and receiving of the signal over the radio path, and is to a great extent a transparent component from the point of view of signalling between the terminal equipment and the higher level of the system. Typical functions of a base station controller include, for example, controlling of radio resources within the base station system BSS, connecting signals between base stations BTS and the rest of the network, controlling macro-diversity, and balancing power control in the whole BSS area.

The structure of a cellular communication system is illustrated in figure 2. The figure shows a number of cells within the system, each cell being served by a base station. The area of the system in the figure is divided into four base station systems A, B, C, and D, so marked in the figure. In a cellular communication system of the invention, the cells located at the border area between base station systems are served by two base stations that belong to areas of different base station controllers. In the figure, these cells are marked by two letters, for example, AB, which cell is thus served by base stations under the control of base station systems A and B.

The operations of the two base stations are independent of each other, but because their coverage areas and propagation conditions are identical, their operations do not interfere with each other. Both of the base stations independently control the transmitting power levels of those terminal equipments to which they are coupled. Both base stations, in addition, operate in the same frequency range, but they employ different spreading codes. Because of the identical coverage area, the interference level to both base stations is identical, and so, the power control functions are balanced as in a situation in which a cell is served by

one base station. It should be noted, however, that the combined capacity of the base stations is the same as in a case of a cell comprising one base station, because the cell total interference, which limits the capacity 5 of the cell, is equal in both cases.

Overlapping cells usually comprise two base stations, but at the corners of base station systems it may be necessary to use a combination of, for example, three or even more base stations. In the example of 10 figure 2, the centre cell, located at the node of four base station systems, comprises base stations under control of four base station controllers A, B, C and D.

In the example of figure 2, there are cells at a depth of one cell, but at the border of BSS areas it 15 is also possible to use overlapping cells at a depth of two cells. The network planning must be so carried out that a situation does not emerge in which a terminal equipment would have to be in a soft handover situation to base stations of different base station systems. A 20 situation such as this can always be blocked, if there is enough depth in the overlapping of cells.

Base stations serving the same geographical area can be implemented in several different ways, some 25 of which are illustrated in figures 3a - 3c. Figure 3a illustrates an example in which base stations have been implemented as units 30, 31 totally independent of each other, and both have separate antennas 32, 33. The antennas should be placed close to one another in order that the radio path of both cells had equal propagation 30 conditions. Each base station is connected to a base station controller 34, 35 of its own.

Figure 3b shows a preferred embodiment of the invention, in which embodiment the base station equipments proper 30, 31 are separate, but employ the 35 same antenna 32. In such a case, the cost of a base

station is lower than in the embodiment mentioned earlier, because the antenna and mast costs are lower.

Figure 3c illustrates a second preferred embodiment of a cellular communication system in accordance with the invention, in which embodiment overlapping base station equipments are implemented by dividing a physical base station equipment 36 into two logical sections 30, 31 which are under control of different base station controllers 34, 35 and employ the same antenna 32. Thus, base stations 30, 31 employ the same physical resources except that the equipment must have separate connections for two base station controllers.

In the following, the method of the invention will be described in closer detail by figure 4. The figure shows two base station controllers BSC1 and BSC2. Of base stations under control of the first base station controller BSC1, base stations BTS11 - BTS14 are shown in the figure. Of base stations under control of the second base station controller BSC2, base stations BTS21 - BTS25 are shown in the figure.

The subscriber terminal equipment MS moves in the BSC1 area towards the BSC2 area. As the terminal equipment moves from one cell to another, the base station controller BSC1 attends to the handovers and the stability of power control. The handovers are carried out as soft handovers so that a connection to the new base station is established before the old connection breaks.

Let us assume that a terminal equipment MS moves from the cell 40 served by the base station BTS12 to the cell 41 which is at the border between said two base station systems. Said cell is served by two overlapping base stations, BTS11 and BTS21. BTS11 is coupled to controller BSC1, and BTS21 is coupled to base

station controller BSC2. As the terminal equipment moves to cell 41, it carries out, controlled by BSC1, a soft handover to a traffic channel of base station BTS11.

Let us further assume that the terminal equipment moves towards the cell 42 and finally into its area. The base station BTS22 serving the cell 42 is under control of BSC2. Before it is possible to activate the base station BTS22 for the handover, the call control must first be switched to base station controller BSC2 from the previous controller BSC1. This is done by a hard handover. The terminal equipment carries out a hard handover from the base station BTS11 to the base station BTS21, and consequently, the base station controller change from BSC1 to BSC2 takes place.

In a hard handover, the spreading code employed by the terminal equipment changes. As the handover, from the point of view of the terminal equipment, is carried out in the same cell, no sudden changes in the power control take place.

If the terminal equipment is at the moment the handover is carried out simultaneously coupled to several base stations which serve overlapping cells, the hard handover is also carried out at these base stations simultaneously. A situation such as this is possible especially in cases there are overlapping base stations at a depth of several cells at the border areas between base station systems.

Thus, the terminal equipment is now under control of base station controller BSC2, and as it moves deeper into the cell 42, it can carry out a soft handover to a base station BTS22 channel in the normal manner.

Although the invention is described above with reference to the examples in the accompanying drawings, it is obvious that the invention is not restricted to

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them, but it can be varied in many ways within the inventive idea of the attached claims.

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## Claims

1. A method for a handover in a cellular communication system which comprises at least one base station (BTS) per each cell, which base station is controlled by a base station controller (BSC) which controls one or more base stations, and which base station controller together with the base stations under its control form a base station system (BSS),  
5 characterized in that at the border of two or more base station systems (BSS1, BSS2), the service areas of base stations under different base station controllers (BSC1, BSC2) at least partly overlap, and that as a terminal equipment (MS) moves from one base  
10 station system (BSC1) to another (BSC2), the handover is carried out so that as the terminal equipment moves into a cell served by two or more base stations (BTS11, BTS21) which belong to areas of different base station controllers, the terminal equipment carries out a soft  
15 handover from the old cell (BTS12) to the new cell (BTS11), and as it further moves towards the cell border, it carries out a hard handover from the base station (BTS11) of the old base station system (BSS1) to the base station (BTS21) of the new base station system (BSS2) the service area of which base station (BTS21) at least partly overlaps with the previous base  
20 station.  
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2. A method as claimed in claim 1, characterized in that if the terminal equipment is at the moment the hard handover is carried out simultaneously coupled to several base stations which are located in cells in which service areas of base stations that belong to areas of different base station controllers at least partly overlap, the hard  
30 handover is simultaneously carried out at all cells.  
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3. A method as claimed in claim 1, characterized in that a hard handover between two base stations (BTS11, BTS21) is activated in cases the connection quality between a terminal equipment (MS) and the old base station (BTS11) deteriorates below a predetermined threshold.

4. A cellular communication system which comprises in each cell at least one base station (BTS) controlled by a base station controller (BSC) which has one or more base stations under its control, and which base station controller together with said base stations under its control form a base station system (BSS), characterized in that at the border area of two or more base station systems (BSS), the service areas of base stations under control of different base station controllers at least partly overlap.

5. A cellular communication system as claimed in claim 4, characterized in that at a border of two or more base station systems (BSS), there are at least partly overlapping base stations under control of different base station controllers at a depth of two cells.

6. A cellular communication system as claimed in claim 4, characterized in that at a cell which is at the node of two or more base station systems (BSS) there are the base stations controlled by all the base station systems bordering said cell.

7. A cellular communication system as claimed in claim 4, characterized in that overlapping base stations (BTS11, BTS21) are implemented by two separate base station equipments.

8. A cellular communication system as claimed in claim 4, characterized in that the overlapping base stations (BTS11, BTS21) have common antennas.

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9. A cellular communication system,  
characterized in that overlapping base  
stations (BTS11, BTS21) are implemented by logically  
dividing one base station equipment to be controlled by  
5 two separate base station controllers (BSC1, BSC2).

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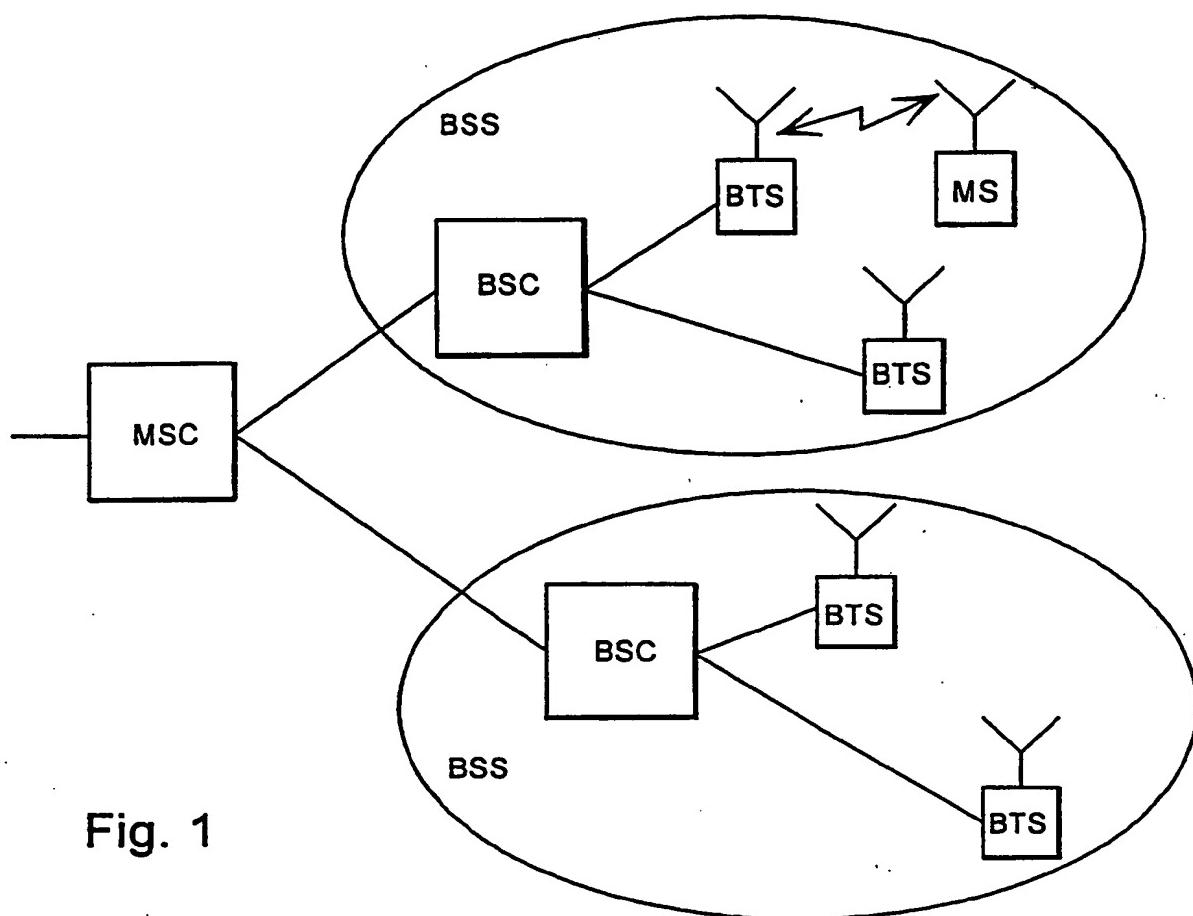


Fig. 1

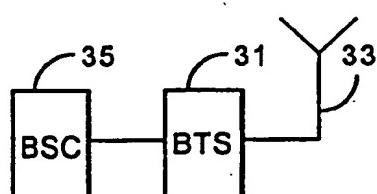
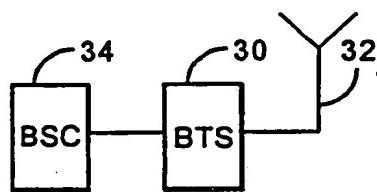


Fig. 3a

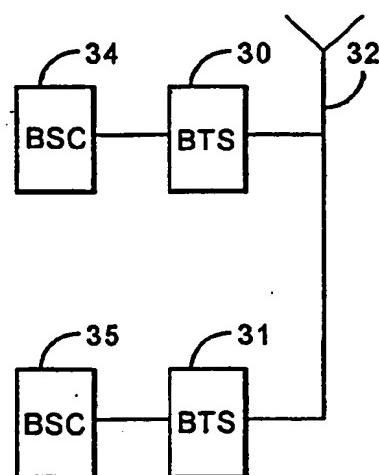


Fig. 3b

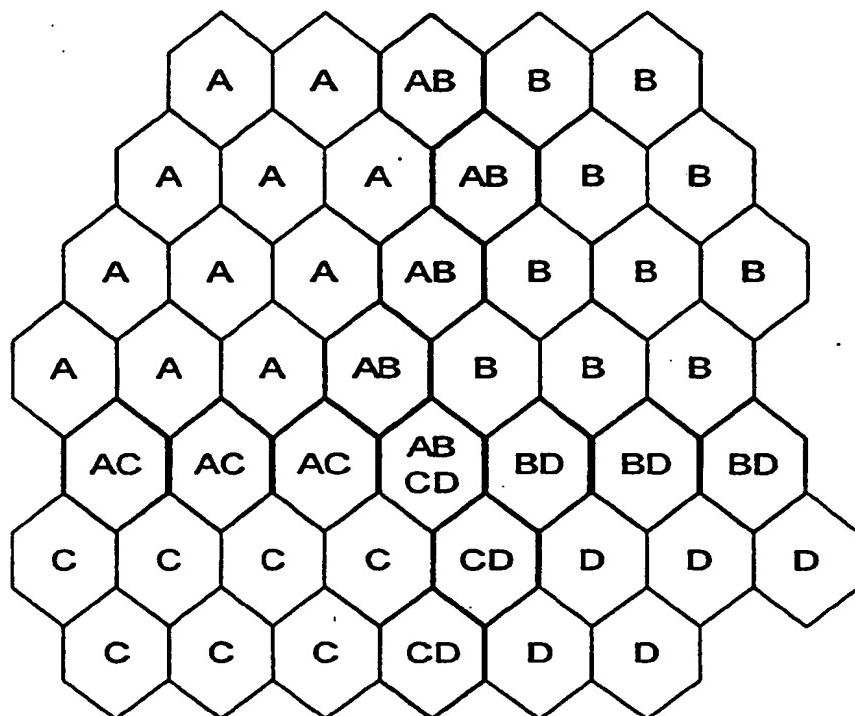


Fig. 2

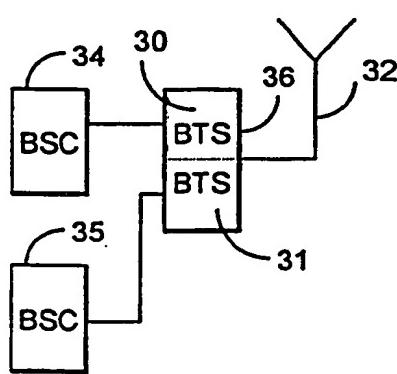


Fig. 3c

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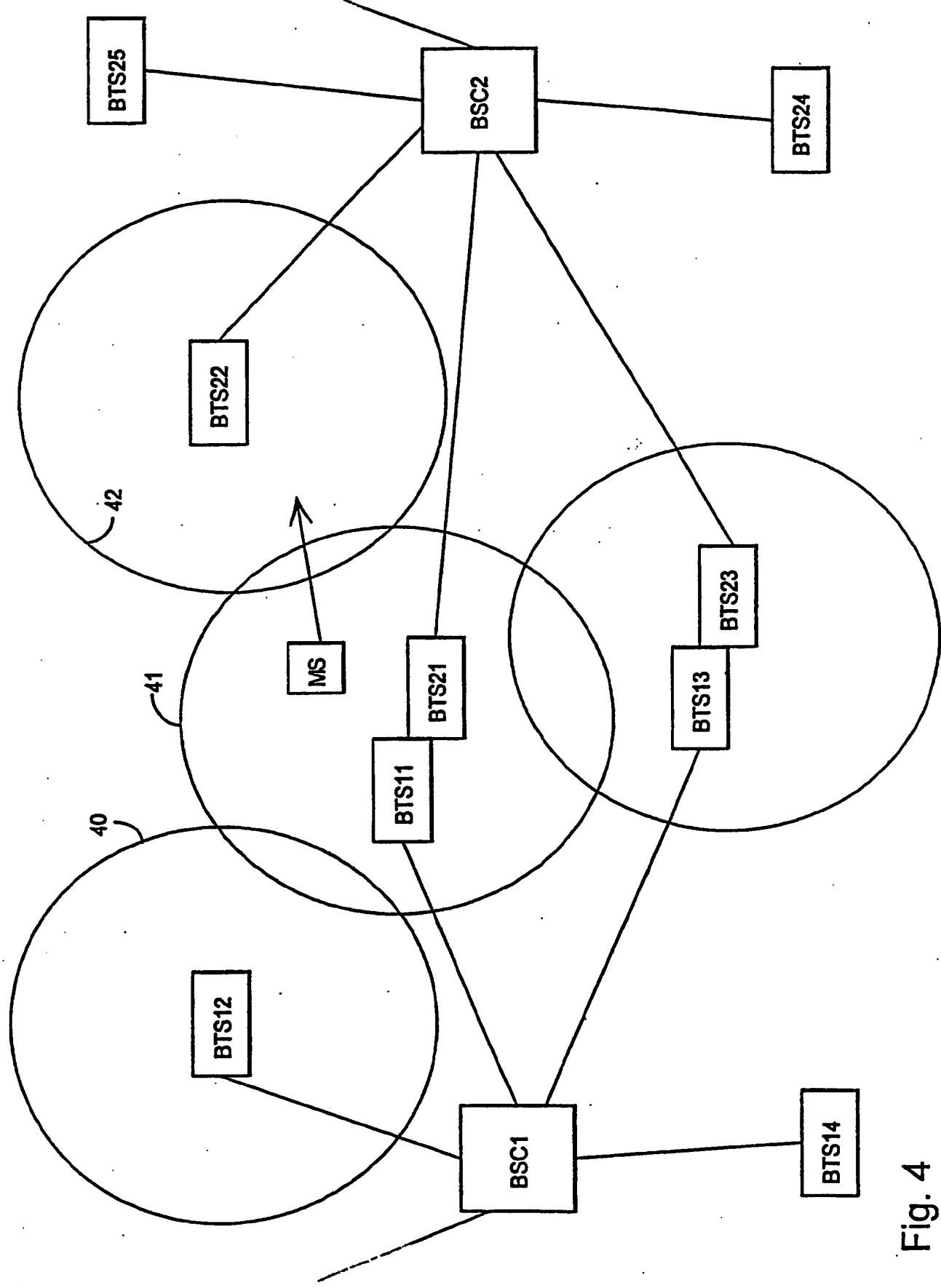


Fig. 4

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